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AUTHOR Itza-Ortiz, Salomon F.; Rebello, N. Sanjay; Zollman, Dean A.

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ABSTRACT

The everyday meaning and usage of several words can differ significantly from their meaning and usage in physics. Examining these differences, and how students respond to them, may shed some light on students' physical learning difficulties. We surveyed (N=154) students in a conceptual physics course on their use of some words, "force", "momentum" and "impulse." We also interviewed some (N=14) of these students to probe their understanding of these terms and to triangulate data collected from the surveys. We found that students who were able to clearly discern the similarities and dissimilarities between the physics and everyday usage scored higher on a class exam that tested these concepts. In the interviews, students who were able to explain the distinction between the physics and everyday meanings often described the words in terms of the physical parameters associated with them. (Author)

The vocabulary of physics and its impact on student learning

Salomon F. Itza-Ortiz, N. Sanjay Rebello & Dean A. Zollman
Department of Physics, Kansas State University, Manhattan KS, 66506

Abstract

The everyday meaning and usage of several words can differ significantly from their meaning and usage in physics. Examining these differences, and how students respond to them, may shed some light on students' physics learning difficulties. We surveyed (N=154) students in a conceptual physics course on their use of some words, "force", "momentum" and "impulse." We also interviewed some (N=14) of these students to probe their understanding of these terms and to triangulate data collected from the surveys. We found that students who were able to clearly discern the similarities and dissimilarities between the physics and everyday usage scored higher on a class exam that tested these concepts. In the interviews, students who were able to explain the distinction between the physics and everyday meanings often described the words in terms of the physical parameters associated with them.

Introduction

The vocabulary of science includes words that we often use in everyday contexts. When we learn science we are often introduced to new and sometimes contradictory meanings of these words. Research (Sternberg, 2001) has shown that we typically learn words in the context of objects and situations. Students bring these associations with them and may misunderstand the words when they are introduced in a physics class. Some researchers (Arons, 1997; Clerk, 2000; Palmer, 1997; Redish, 1994; Gilliespie, 2001) classify this confusion as a misconception.

Researchers have studied semantics in physics (Touger, 2000; Williams, 1999, 2000) and meanings of words (Touger, 1991; Styer, 2000; Hart, 2002). However, the problem goes beyond semantics (Touger, 2000). The linguistic relativity hypothesis by Sapir and Whorf (Sternberg, 2001) states that "we see, hear and otherwise experience very largely as we do because the language habits of our community predispose certain choices of interpretation". An upshot of this hypothesis is that although language may not determine thought, it certainly may influence thought. Most research (Touger, 1991, 2000; Williams, 1999, 2000; Styer, 2000; Hart, 2002) has not discussed this relationship closely. This study will address that relationship.

In this paper, we address the question: Do the differences in the use of words between everyday life and physics inhibit learning of physics? We focus on three words that are common in any introductory physics course: "force", "momentum" and "impulse". We surveyed and interviewed students in a conceptual physics class at Kansas State University. Our findings enable us to suggest strategies that help students incorporate the physics meaning of these words into their vocabulary.

Research Goals & Methodology

Our goal was to study how students perceive the similarities and differences between the everyday meanings and physics meanings of the words and whether these perceptions affect conceptual learning in physics. Our research subjects were 154 non-science majors in a conceptual physics course. About 57% of the students had previously taken a physics course. Our research was conducted in three phases: pre-survey, post-survey, and an interview.

The pre-survey was administered before the relevant physics terminology was introduced. We asked students to construct three different sentences using the word (or its variant). Thus, the pre-survey told us how the students use the word in their everyday vocabulary. We categorized the sentences based on the usage of the word: Animate Verb, used as a verb associated with a person or animal; Inanimate Verb, used as a verb associated with an inanimate object; Noun; and Adjective or Adverb when describing an object or action.

The post-survey was administered after the term was introduced in class. We presented four sentences to the students each containing the word (or its variant). These sentences were selected from

among those written by students on the pre-survey. We asked students to explain the similarities and dissimilarities between the words used in each sentence, and their physics usage.

The post-survey results were classified into three categories: Category 1 includes students who can explain how the word "force" in each sentence, is both similar and dissimilar to the word "force" in physics; Category 2 includes students who are able to describe these similarities and differences for only a few of the given sentences; and Category 3 includes students whose responses indicate they cannot explain these similarities and differences for any of the given sentences. The validation of the categorization was done by an independent researcher who did the categorizing of the sentences independently. The validity was found to be 83%. Immediately after the post-survey the instructor administered a scheduled class test covering the topic of force. For our analysis we focused on the score for the questions relevant only to force, nine out of a total of 26. The questions were multiple-choice, only 2 of them required numerical calculations; the other seven questions were conceptual. These conceptual questions were similar to the ones in the Force Concept Inventory (FCI) (Hestenes, 1992).

We triangulated our survey data by interviewing 14 students toward the end of the course. The goal of the interview was to probe student understanding and use of these terms. The interview protocol was based on questions on the written surveys.

Research Findings

The word "force"

59% of sentences on the pre-survey included the word "force" as a verb. This data is consistent with the fact that the word "force" is most often used as a verb in everyday language (Styer, 2000; Hart 2002). 36% of the students in the second survey were in categories 1 and 2, *i.e.* they described the similarities and differences between the meaning of the word "force" in the given sentences and its physics meaning. The remaining 64% of the students, category 3, were not able to differentiate between the everyday and the physics meaning of the word force. Comparison of test scores for each category, shows that students who can identify and explain the physics meaning of the word "force" obtain higher test scores, thereby establishing a link between the linguistic ability of students and conceptual understanding, as measured by the test.

Our 14 interviewees included representatives from each of the three categories. In the interviews the students first wrote two sentences using the word "force" (or its derivative). They were asked to describe whether the word "force" as used in their sentences was similar or dissimilar from its physics usage. All of the interviewees were able make this distinction. When asked to explain why the word had a physics meaning almost all stated that the word relates to "*pushing*", "*pulling*" or "*motion*". When asked to explain why the word had an everyday meaning, they said it has to do with "*mental power*", "*following rules*", but "*not in any physical sense*". Their explanation for the physics meaning is consistent with what they were taught in class: that force is "any influence that tends to accelerate an object; a push or a pull". They also were taught that force equals mass times acceleration. Only 2 out of the 14 students were able to relate force to the mass of the object and/or its acceleration. In the everyday vocabulary "force" is not related to these terms, therefore the students do not use them. This finding supports the Sapir-Whorf (Sternberg, 2001) hypothesis.

In the second part of the interview the students were given four sentences and again asked to identify the meaning of the word "force" in each sentence. Again, all students were able to identify whether the meaning corresponded to everyday life or to physics because they focused on the context of the sentence. However, only two of the 14 students were able to explain how the meaning of the word is similar and/or dissimilar to its meaning in physics. These two students were also the only ones who associated force with mass and acceleration. For example when a student was asked to explain the meaning of the word force in physics she said "*Force is weight, force of a book onto a table; force of a person while pushing a chair across the room.*" When this same student was asked to explain the meaning of the word force in the sentence "The bulldozer forced the rock into the ditch," she said, "*the bulldozer has direct contact onto [sic] the rock, pushes the rock.*" She identified force as a push, from the definition of force. Another student stated that, "*Force causes movement, there are forces everywhere, like friction. Force is*

mass times acceleration." When this student was asked to explain the meaning of the word force in the bulldozer sentence he/she said "*the bulldozer moves the rock into place, there is mass and acceleration.*" The latter student is using the physical variables involved in force to explain why the word force in the sentence has a physics meaning. Thus, those students that relate the word to physical variables are more likely to explain the meaning of the word in physics.

The words "momentum" and "impulse"

Momentum and impulse were discussed in class, after the topic of force. 80% of the students' sentences used the words as nouns in the pre-survey. Again, this is consistent with the most common usage of these words in everyday language. 36% of the students from categories 1 and 2 of the post-survey were able to explain how the words in the sentences provided were both similar and dissimilar to the words as used in physics. Students in category 1 scored higher on the test than students in categories 2 and 3. These results are similar to results for the word "force," therefore reinforcing the link between the linguistic ability and conceptual understanding.

In the interviews we asked students to write two sentences each using the word "momentum" and "impulse." 12 students interpreted the meaning of the word "momentum" in the physics context. However, only 6 of them related momentum to mass and or velocity. When asked to explain the physics meaning of "momentum", typical responses included terms such as the "*mass of the object*", "*speed*", "*action*", "*motion*" or "*build up of energy*". When asked to explain the everyday meaning of "momentum" typical responses included "*feelings*", "*mental action*", "*not necessarily physical motion*". It is interesting to note that momentum has a Latin root which means "movement". The everyday meaning of the term is quite similar its physics meaning. It appears that due to this similarity, students are more likely to be able to explain the physics meaning of the term. For instance, when asked to explain the meaning of the term momentum, one student said, "*When someone is running, he has mass and speed, he is creating momentum.*" Another said, "*Momentum is, ... as something falls speeds up... gains speed, gains momentum.*" Only one of the 14 students was able to explain the physics meaning of the term "impulse". The explanations of all of the other students corresponded to the everyday meaning of the term -- "*instant action*", "*spontaneity*", "*something you do without thinking*". The dictionary meaning of the word impulse is "a sudden spontaneous inclination or incitement to some usually unpremeditated action". This meaning of the word is deeply embedded in students' minds and it is difficult for them to relate it to physics. In fact the physics meaning of the term --, the magnitude of a force multiplied by the duration for which it acts, is quite different from the everyday meaning. In fact, the two meanings are almost contradictory. In everyday language, an impulsive action is associated with a short time duration, while in physics the longer the time duration, the greater the impulse. It appears that this difference makes it difficult for students to understand its physics meaning. Both students who correctly relate "momentum" to its physics meaning are unable to do so for "impulse." Overall, the word "momentum" seems more intuitive to the students than the word "impulse", because everyday and physics meanings of the word are quite different from each other. The Sapir-Whorf[1] hypothesis seems to be applicable here. The everyday meaning of these words poses a barrier to understanding and assimilating the word in their physics vocabulary.

Conclusions

We surveyed 154 non-science majors in a conceptual physics class to study their perceptions of the similarities between the everyday and physics meanings of three commonly used words. Our findings show that students who can differentiate between the everyday and physics meanings of the words, and can explain the physics meaning, are more likely to obtain higher test scores.

Findings from our interviews indicate that students who are able to identify or remember physical variables related to the word are more likely to explain its physics meaning. Our findings also indicated that some words (e.g. "momentum") seems more intuitive to the students, in that they always relate it to motion, and therefore are more easily able to understand and assimilate this word in their physics vocabulary. Other words (e.g. "impulse") that have an everyday meaning different from their physics

meaning, are harder to understand and assimilate. Our findings are consistent with the Sapir-Whorf (Sternberg, 2001) hypothesis.

Impact on Instruction

Learning is often (Maloney, 1993) described as the acquisition of a different understanding of a concept that coexists and often competes with previous informal understanding. In this light, our findings indicate that physics instructors should be more cognizant of the use of language and the alternative meanings of physics terminology that their students bring with them to the class. We propose that comparing everyday and physics meanings of words will help students to assimilate the physics meaning of the word in their vocabulary. We do not believe the physics meaning of words will take the place of the everyday meaning but rather they would always coexist. Some instructors (McGuire, 2002) have suggested asking students to write essays using these words in different contexts. These different contexts would enable students to confront the very different use of these words in physics and everyday language. Many of the students in conceptual physics classes, such as humanities majors, have strong writing ability, and may find such writing tasks to be quite enjoyable. Efforts to inculcate superior writing skills across the curriculum have been used in several high schools and colleges. The writing exercises described above may have a unique role in such a curriculum.

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